Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
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Methanol and excited OH masers in W49N as observed using EVN

Anna Bartkiewicz[1], Marian Szymczak[1], Agnieszka Kobak[1], and Mirosława Aramowicz[2]

[1]Insitute of Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland
[2]Astronomical Institute, Department of Physics and Astronomy, University of Wrocław, Kopernika 11, 51-622 Wrocław, Poland

Abstract. We imaged the excited OH maser line at 6.035 GHz associated with the 6.7 GHz methanol masers in a selected sample of high-mass young stellar objects using the European VLBI Network. The excited OH emission was found in a survey of methanol maser sources carried out since 2018 with the Torun 32-m telescope. The overlap of radial velocities of spectral features of methanol and excited OH suggested that both lines arose in the same volume of gas, therefore, we verified this hypothesis with the interferometric data. Here, we present the first images at the milliarcsecond scale of both maser transitions and identify the Zeeman pairs at the ex-OH line estimating the strength of the magnetic field in G43.149+00.013 (W49N).

Keywords. methanol maser, exited OH maser, magnetic field, Zeeman pairs

1. Introduction

Significant contributions to our knowledge of the formation of high-mass young stellar objects (HMYSOs) came from VLBI observations of cosmic masers, mainly methanol and water transitions. Since a large survey of the 6.7 GHz methanol maser line using the Torun 32-m dish (Szymczak *et al.* 2018) was completed by the survey at the excited OH maser line at 6.035 GHz (ex-OH hereafter) (Szymczak *et al.* 2020), we were encouraged to start to follow up studies using European VLBI Network (EVN)† C-band receivers but now at the opposite edge to the methanol line. As a pilot project, we selected the brightest source G43.149+00.013 (known as W49N), where the radial velocities of spectral features of methanol and ex-OH overlapped suggesting that both lines arise in the same volume of gas.

2. Observations

We observed the HMYSO W49N on 2019 June 3 at the 6.035 GHz OH transition in the phase-referencing mode using J1912+0518 as a phase-calibrator. Useful data were obtained from seven EVN antennas: Effelsberg, Irbene, Jodrell Bank, Medicina, Onsala, Torun, Westerbork. The rms and synthesized beams on the final images in two circular polarizations (RHC, LHC) were 8 mJy and 15×5 mas with a position angle of -5°, respectively. The spectral resolution was 0.097 km s^{-1}.

3. Results and Discussion

We imaged the ex-OH masers related to the southern component of W49N, the G43.149+00.013 source (Fig. 1). This source showed intermediate brightness of the 6.7 GHz methanol masers compared with other components of W49N, i.e.: G43.165+00.013,

† The European VLBI Network is a joint facility of independent European, African, Asian, and North American radio astronomy institutes. Scientific results from data presented in this publication are derived from the following EVN project codes: EB073.

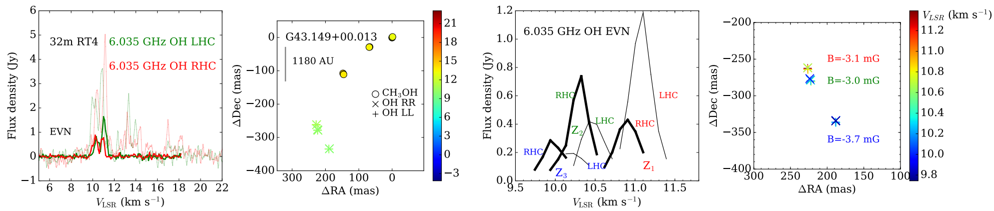

Figure 1. The ex-OH and 6.7 GHz methanol masers in G43.149+00.013 region of W49N. From left to right panels, we present 1) the 32-m Torun dish and EVN spectra, 2) the distributions of both masers, 3) the spectrum of LHC and RHC polarised emission, and 4) the distribution of the polarised masers. The colours of maser spots correspond to the LSR velocities as indicated on the vertical bars.

G43.171+00.004, and G43.167−00.004. According to the evolutionary sequence for masers proposed by citepbreen2010, the G43.149+00.013 would be the most evolved region in W49N. However, the single-dish observations show some emission at the higher LSR velocities (from 12 to 15 km s^{-1}) that was not recovered in imaging and extensive and sensitive searching for ex-OH emission is required.

The single-dish monitoring indicates that the 6.7 GHz methanol line is non-variable (Szymczak *et al.* 2018), so we can assume the stability of methanol maser morphology. The displacement of both maser species is clear, about 200 mas, corresponding to 2200 AU for a distance of 11.1 kpc (Zhang *et al.* 2013). No co-existence was detected indicating the diversity in densities of the maser-emitting regions (Cragg *et al.* 2002). However, we note the 6.7 GHz methanol maser images were obtained in 2010 (Bartkiewicz *et al.* 2014), therefore, simultaneous observations are required (see Kobak *in this volume*).

The interesting result, for which we aimed, is the detection of three Zeeman pairs; only the interferometric data can verify the existence of Zeeman pair components. We detected three maser clouds, where LHC and RHC 6.035 GHz OH emission coincide and their velocity profiles are shifted (Fig. 1). We calculated the magnetic field strength (B) as ca. 3.5 mG oriented towards us taking the coefficient of 0.056 km s^{-1} mG^{-1} (Baudry *et al.* 1997).

4. Summary

We present the use of EVN to study gas properties in the environment of HMYSO using the 6.7 GHz methanol and 6.035 GHz ex-OH masers. The first results for W49N indicate the avoidance of both maser lines at the mas scales and the diversity in densities of the maser-emitting regions (Cragg et al. 2002). We confirm the existence of Zeeman pairs as it was proposed in the single-dish studies (Szymczak et al. 2020).

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